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Engineered Solutions: The Next Generation of Nuclear Safety Improvements in the DOE Complex

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Opportunities to Improve Nuclear Safety

- Brief History of Nuclear Safety
  - How Did We Get Here and Where Are We Going?
    - NRC Perspective
    - DNFSB Perspective
- Administrative Solutions and Engineering Solutions R&D
- Opportunities to Improve Nuclear Safety
- Supporting Models with Empirical Data
- Improving Facility Response to Design Basis Accidents
  - Improving Facility Seismic Response
  - Improving Facility Response to Other Accidents
  - R&D Opportunities
    - Problems with Existing Technology
    - Next Generation HEPA Filters
      - Benefits
      - Potential Applications
- *DOE research can lead to tangible safety improvements and is cost effective*

Brief History of Nuclear Safety

- How Did We Get Here and Where Are We Going?
  - Manhattan Project
    - — Early Vendors, Aquariums, and Wood Gloveboxes
  - 1954 Atomic Energy Commission (AEC)
    - — Funded nuclear safety R&D
  - 1975 Nuclear Industry Matures: Separation of Commercial Nuclear Industry from Government/Defense Activities
    - — NRC (Office of Nuclear Regulatory Research)
      - – Budget of ~ $68M (FY 07) with 243 FTEs, down from high of $200M in 1970's
      - – Plant aging, materials research, weld cracking, instrumentation and controls, fire research (e.g., cables), alternative/less dispersible sources, etc.
      - – NRC currently participates in over 75 international cooperative research agreements, such as the Halden project in Norway, and the Prisme program in France.
    - — NEI, EPRI, Utilities, Vendors
    - — DOE and Predecessor Organizations (ERDA)
      - – Research collected by Mishima in DOE-HDBK-3010
      - – National Laboratories, Corporate Research
      - – Budgets Decline
        - » Only limited engineering solutions R&D
  - 2004 to 2009 DNFSB concerns on amount of nuclear safety R&D being funded

Brief History of Nuclear Safety - NRC

- How Did We Get Here and Where Are We Going? (cont'd)
  - NRC Perspective
    - NRC continues to support an active regulatory research program
    - NRC research benefits a large number of facilities
      - New reactors are not the greatest challenge
      - Current operating fleet is of "paramount importance" given aging issues
      - License renewal, to allow current 40 year licenses to be extended for an additional 20 years, has identified a number of areas
        - » Utilities have invested significant sums of money into replacement components and upgrading equipment

[*An Overview of the NRC's Office of Nuclear Regulatory Research*, Brian W. Sheron, Director, Office of Nuclear Regulatory Research, NRC]

Brief History of Nuclear Safety - DNFSB

- How Did We Get Here and Where Are We Going?
- DNFSB Perspective
  - DNFSB Recommendation 2004-1
    - Discussed “apparent absence of a strong safety research focus”
    - DOE needs to take steps to “ensure the continued integration and support of research, analysis, and testing in nuclear safety technologies”
  - Remarks by Larry W . Brown, Member, DNFSB to the DOE Nuclear Safety R&D Forum, Feb. 18, 2009
    - Reiterated the need for and concern for not doing cost effective research
    - Specifically highlighted cost-benefit of doing the research on HEPA filters, hydrogen deflagration, thermolysis, and airborne release fraction
    - Believes identifying and prioritizing crosscutting nuclear safety R&D will have measurable results

Recent Events Highlight Need for R&D

- Recent activity in nuclear energy has been substantial
  - As of June 2006, 42 U.S. plants had received 20-year license renewals, 8 were under review, and 23 were planned for submission by 2010 (70% of U.S. plants total).
  - Announcements for new Combined Construction and Operating Licenses (as of October 2008):
    - COL applications for 20 plants already submitted
    - Total existing or expected COL applications: 21 plant sites, 31 plants [now 32 per NRC FY 2009 budget report]
  - ITER Starts construction, 2008
  - National Ignition Facility comes to full power, March 2009
    - [Source: *UC Berkeley Nuclear Engineering Science Teacher 2009 Workshop, Prof. Per Peterson presentation*]
  - DOE continues to operate a large number of legacy radiological, nuclear, chemical, and biological (BSL) facilities
  - DOE has built and is building important new nuclear facilities
    - Several key new nuclear facilities

Administrative and Engineering Solutions

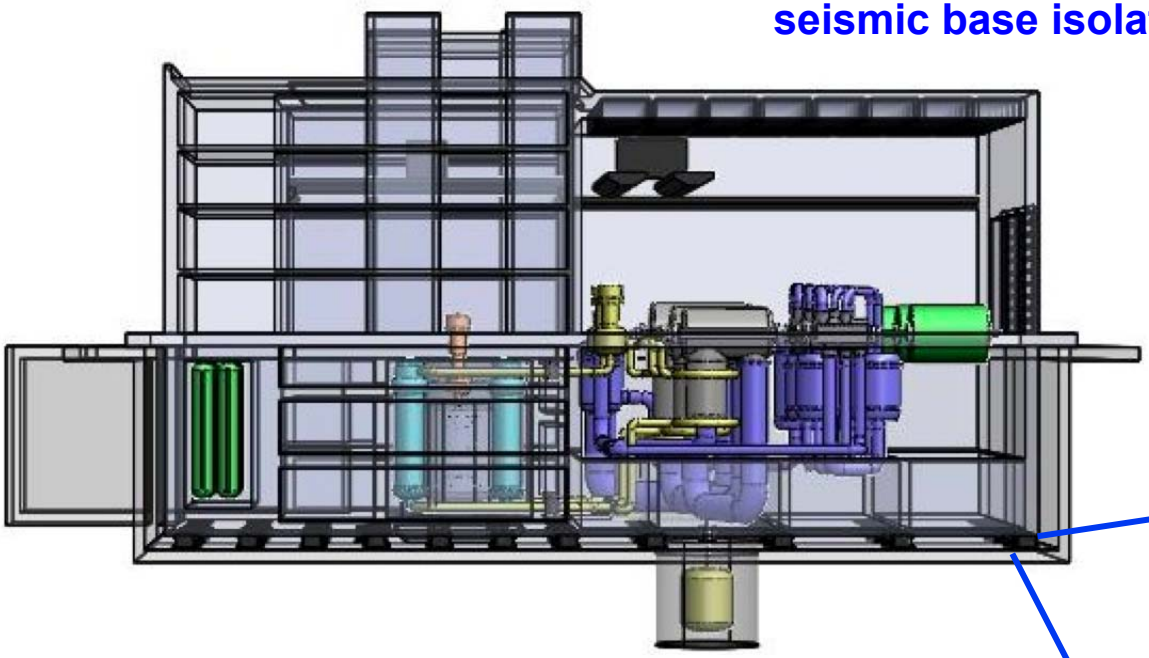
- DOE-STD-3009 conveys a philosophy of emphasizing engineering controls in preference to administrative controls when possible
- Budget realities focused improvements on administrative/regulatory controls over engineering solutions (R&D and backfitting)
  - Improve administrative controls with DOE-STD-3009 Safety Management Programs (SMPs) and DOE-STD-1186 Specific Administrative Controls (SACs)
  - Improve integration of safety into design with DOE-STD-1189
  - Improve compliance by transitioning from Orders to 10 CFR 830, 10 CFR 835, and 10 CFR 851
  - Limited budgets for R&D
  - Limited budgets for backfitting

Supporting Models with Empirical Data

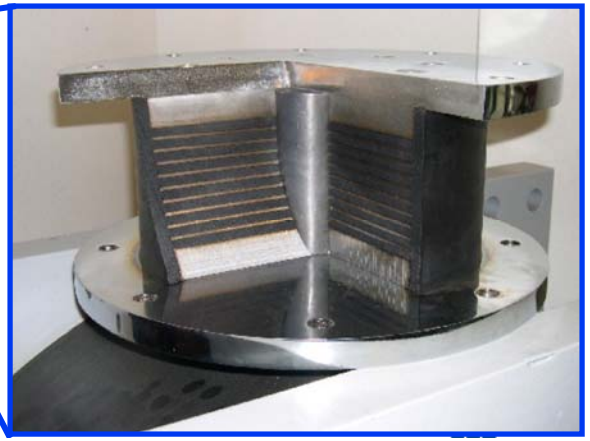
- DOE started programs to improve nuclear safety
  - Call for proposals
    - — Highest priority were experiments to obtain empirical data supporting models (e.g., Melcor for leak path factor)
    - — Funding decreased and staff turnover led to DNFSB comments
- Other regulatory research efforts in the DOE Complex
  - Toolbox Codes
  - V&V of revised codes (e.g., LLNL, LANL, and Omicron)

Improving Facility Seismic Response

Hearst Mining Building at UC Berkeley uses seismic base isolation



Grade level



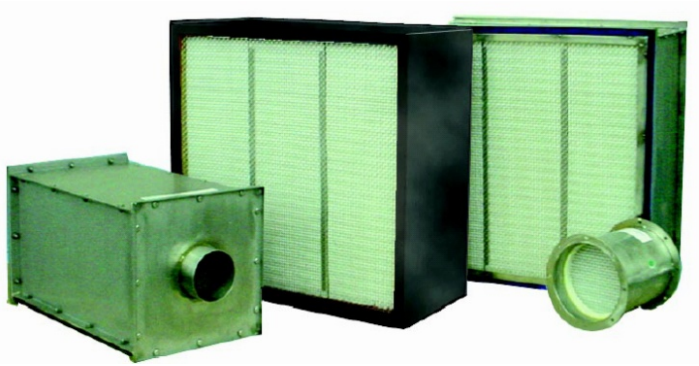
Modular PB-AHTR Concept proposes seismic base isolation

- Structure isolated with resonant period of 3.6 seconds
- Isolators filter out higher frequency seismic energy

[Source: ***UC Berkeley Nuclear Engineering Science Teacher 2009 Workshop, Prof. Per Peterson presentation*****]**

Improving Facility Response to Other Accidents

- Problem: Fires, Spills, and other Radiological Releases
  - Changes to Fire Suppression System
    - — Changes Driven by Environmental Concerns
  - Ventilation System Improvements
    - — Improvements in Ventilation System Designs (e.g., Flash Arrestors, Demisters)
- OFI: Filter Function in Accidents and Operations
  - Nuclear, biological, and chemical (NBC) filters important in diverse applications
    - —High Efficiency Particulate Air (HEPA) filters mitigate release of particulates during an accident
    - —Process filters remove airborne particulate from gas stream
    - —Filters may be used in conjunction with other media to treat gases in process gas stream (e.g., scrub pollutants)
    - —Sand filters are often not the optimal solution



The Joys of Living with HEPA Filters

R&D Opportunities – Problems with Existing Technology

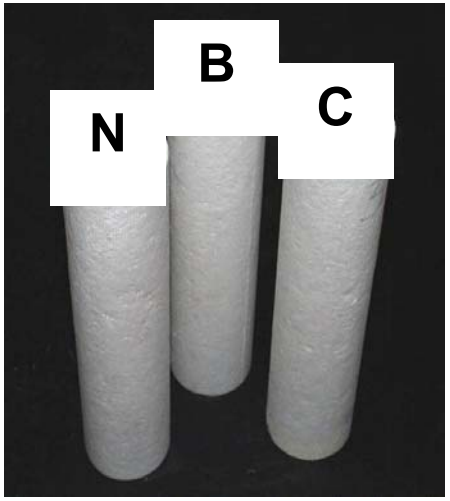
- **Response to Fire Scenarios**
  - Typical HEPA Filters Contain Glass Fiber and Polymer Materials
  - Typical DOE Complex HEPA filters
    - 250^{o}F maximum temperature for DOE nuclear facility
    - However, extended service under such conditions can cause ACCELERATED aging…may subsequently contribute to filter failure
    - Three year shelf life IF stored in environmentally controlled conditions
  - Current High Temperature HEPA Filters
    - Survive up to 1000^{o}F(exhaust air) & 500^{o}F (supply air) for <2 hrs
    - Do not meet all regulatory requirements
    - Exhibit a significant loss of strength after the binder burns off (300-325^{o}F range)
    - Polymer components degrade under continuous exposure to temperatures above 392^{o}F

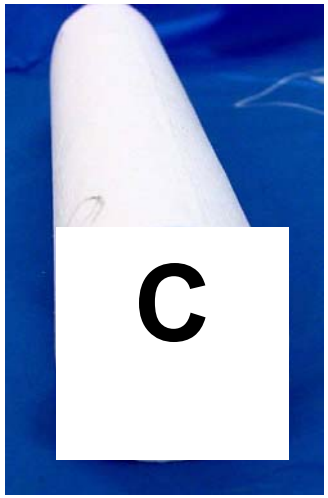
R&D Opportunities – Problems with Existing Technology (cont'd)

- **Other HEPA Filter Performance Issues**
  - Lifecyle Cost
    - Operational life drives maintenance and waste costs
    - Regulatory expenses
  - Other Performance Issues
    - Filters may plug during process operations involving particulates or during a fire
    - Reactive medium may become deactivated during use
    - Removal of filters and/or reactive medium requires shutting down the ventilation system or process gas stream
    - Frequent removal may result in ALARA and RadCon issues
    - Damaged by high pressures, chemical attack, water, fire, and high temperature
    - Unable to handle operational requirements in corrosive, moist environments
    - Pre-filter technologies not allowed by regulators in some key industries (e.g., Teflon©)

Next Generation Ceramic Filters Can: Increase Performance and Safety, and Lower Cost

- **Objective**
  - Designed to meet DOE and commercial requirements, as well as to minimize upgrade installation logistics for use in existing facilities
  - Current key performance requirements described in DOE-STD-3020
  - Designed for:
    - High temperature resistance
    - High strength
    - Fire resistance
    - Corrosion resistance
    - Moisture resistance





- **Superior performance, wider operational range**
  - Superior performance during facility fire
  - Can perform safety function even when wetted and exposed to greater pressures
    - Facilities are often designed with HEPA-filtered exhaust systems and water-based fire suppression systems
    - Traditional HEPA filters subjected to wetting to protect them from high temperature are substantially weakened
  - Increase safety of operations
  - Optimize overall system performance
  - New process opportunities for industry
    - Fills a gap in filtration technologies

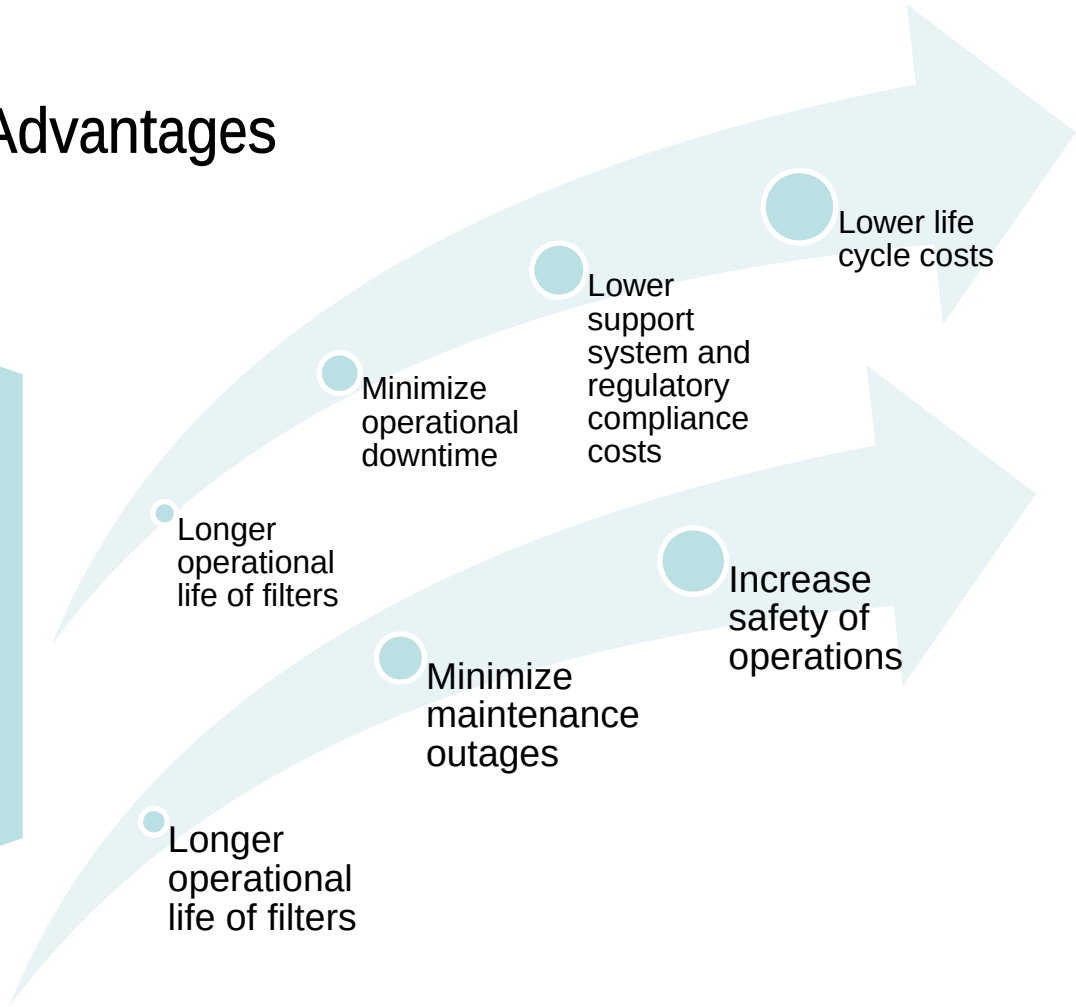
R&D Opportunities – Benefits

- Ceramic filters have the potential to:
  - Significantly increase filter life span
  - Reduce life cycle costs,
    - Reduce affiliated support system costs, regulatory compliance costs, and waste disposal costs
    - Reduce maintenance downtime/increase operational efficiency
    - Increase safety of operations
  - Open up new opportunities for overall process gas system and ventilation system design
    - Open up industrial processing avenues closed by current technology & regulations
    - LLNL process innovations allow continuous operation

Deploying the Results of R&D Can Benefit Entire DOE Complex

Ceramic HEPA Filter Advantages

Replace existing filters with more durable versions with enhanced capabilities and open up industrial avenues closed by current technology & regulations



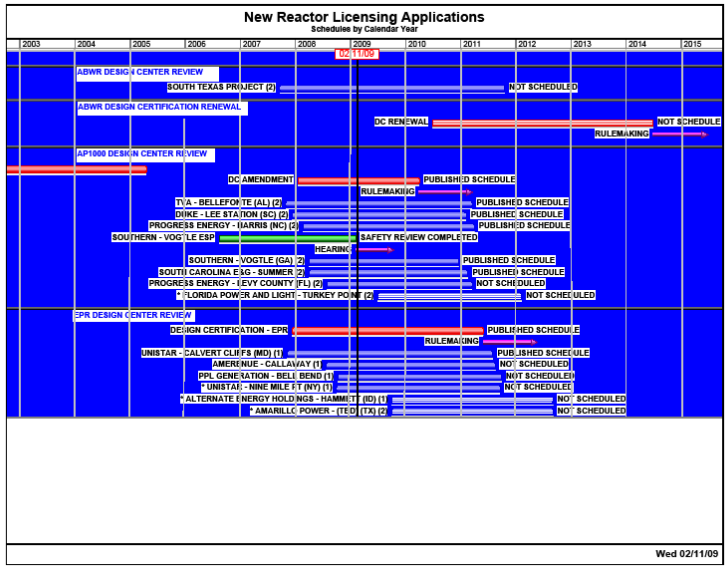
Potential Applications:
New and Existing Industry Markets

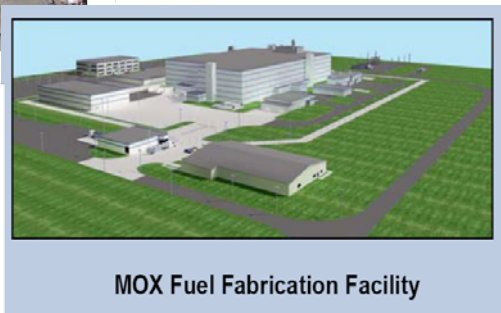
Commercial Applications

- Biotech/Biopharmaceutical Manufacturing
- Pharmaceutical Manufacturing
- Clean Coal Power Generation
- Hazardous Chemicals Processing
- Mining
- Metals Processing
- Wastewater Treatment
- Agriculture
- Semiconductor Fabrication

DOE/DOD/NRC Applications

- Aerospace Manufacturing
- Defense Industries
- Petroleum Processing
- Nuclear Power Generation
- Non-reactor Nuclear Facilities such as those under construction at Hanford, Y-12, and Savannah River





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Conclusion

- Safety R&D is beneficial to DOE and contractors
- Spending money on research will:
  - Decrease life cycle cost to DOE
  - Decrease risk acceptance by DOE
  - Increase safety
- A few proposals were highlighted, much more can be done
- Advantageous to DOE and contractors to prioritize focus of fundamental research on engineering safety solutions (hardware) rather than primarily additional analysis
- New Administration wants to reduce costs and put out a call for ideas
  - “Shovel ready” projects
- **Regulatory R&D can be wise stewardship of tax payer dollars, leveraged across the entire DOE Complex**